Expert Memory and Instrumental Conductors:

Interactions between Long-Term and Short-Term Memory

by

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A Research Paper Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Musical Arts

Approved April 2017 by the
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May 2017

ABSTRACT

By examining the cognitive mechanisms behind human memory, the author hypothesizes that instrumental conductors can more quickly and effectively internalize music scores. With this theory, conductors could offer more informed and nuanced communications to their ensembles. Furthermore, these ideas could be incorporated into how conducting is taught to younger students by cultivating a more in-depth understanding of the music being studied.

This research paper surveys current trends in cognitive science related to the interactions of long-term memory (LTM) and short-term memory (STM) concerning score study and memorization employed by instrumental conductors. The research is divided into three sections, beginning with an examination of the key literature from the field of cognitive science. It continues with an overview of current musicological research and applications and finally concludes with a review of current instrumental conducting pedagogy that include discussions of memory. Moreover, recommended steps and a potential framework to incorporate cognitive science research into future conducting pedagogies are further outlined. The primary cognitive theory of focus is the Working Memory Theory of Alan Baddeley and Graham Hitch.

DEDICATION

To Honey

ACKNOWLEDGEMENTS

Many people both directly and indirectly had a hand in this document's completion. To begin, I have to acknowledge all of the music educators and conducting mentors I have through the course of my education. I could not have written this document without the lessons I first learned from them. Additionally, my chair, Jason Caslor, deserves much thanks for the work I have accomplished here, which is a result of his mentorship and direction.

My entire family has been my biggest supporters since I started down this path, especially my mother, father, brother, and grandparents. They all have been nothing short of amazing ever since I told them I wanted to pursue music instead of chemistry, and I would not have gotten far at all without their help.

Finally, my wife, Leisha, has been a tremendous support. I always rely on her as a source of steadiness and resolve during challenging times, and she was also one of the driving factors behind this research (more on that later). I owe to her everything I have accomplished to this point!

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"And finally, what about the magical number seven? What about the seven wonders of the world, the seven seas, the seven deadly sins, the seven daughters of Atlas in the Pleiades, the seven ages of man, the seven levels of hell, the seven primary colors, the seven notes of the musical scale, and the seven days of the week?"

-George A. Miller

CHAPTER 1

INTRODUCTION

Catalyst for Study

The motivation for this research was a natural outgrowth of my time at Arizona State University (ASU). During my tenure at ASU, I continually honed my own score study process in the hopes of more quickly and efficiently learning the various repertoire for which I was responsible. I also noted that many of the conductors that worked with the ASU ensembles seemed to have an enhanced ability to internalize and memorize scores—one particular area of score study with which I had continuously struggled.

At the height of my curiosity, guest conductor Carl St. Clair visited campus to conduct the ASU Symphony Orchestra in a concert featuring Shostakovich's tenth symphony. After observing him rehearse for several hours while only occasionally referencing the score and subsequently conduct the entire concert from memory, I asked him if he had a particular method or approach to memorization. He described how, regardless of the actual length of the piece, he would continuously group small units of music together to form larger chunks until an entire symphony would be no more than five large pieces in his mind. I later recalled this same story with some wide-eyed disbelief to my wife (one with advanced degrees in psychology and counseling) who informed me that this phenomenon indeed existed and had been studied in some depth across various disciplines. She further explained that according to some research, the human memory had a finite limit on the amount of information it could recall, so it naturally "chunked" units of information into larger pieces and allowed humans to exceed this seemingly narrow memory limit. From that point, I began searching for more information on the subject and uncovered a wealth of resources in the field of cognitive science. Those initial searches grew into the survey below.

Introductory Impressions

While every conductor internalizes the score to some degree in an effort to better communicate with their ensemble, the methods by which each individual attempts this is highly variable. In the classroom, most conducting textbooks and supplementary texts encountered by students offer a cursory section on score study, at best, thus leaving the student to develop their own approach through trial and error or coincidence, rather than through a specific, measured effort. These processes outlined in various texts usually focus on compositional features such as harmony, phrase analysis, and form. However, one aspect of conducting exists that often seems an afterthought in textbooks or even overlooked entirely: cognition. Yet, we marvel at the maestro who conducts a Mahler symphony from memory, often rationalizing the feat as a talent few are born with that is otherwise unattainable. While, on the surface, it seems that memory work comes easier to some than others, studies from the field of cognitive science exist that can assist conductors, both student and mentor, in better internalizing the scores they are preparing.

Definitions

The field of cognitive science is relatively young and thus, still evolving. Moreover, due to its interdisciplinary nature and the various theories being constantly revised and improved upon, field-specific jargon is not always consistent. For this reason, I have elected to define several key words and ideas early on so as to avoid confusion:

1) Short-term memory (STM) – first part of most multi-component models of human memory; immediately encountered environmental information is stored here before decaying quickly
2) Long-term memory (LTM) – second part of most multi-component models of human memory; holds information deemed important enough for future recall with significantly slower decay; retrieval from LTM requires conscious effort
3) Working memory (WM) – earlier used as a substitute for STM; now refers to the theory of Alan Baddeley and Graham Hitch; environmental information that is actively focused on by the subject for rehearsal, storage, or recall
4) Sensory Modality – method of sensing environmental stimuli
5) Chunking – cognitive tool in which small units of information are combined into larger, more meaningful units; e.g., ten-digit telephone numbers being chunked into three groups of digits

Other field-specific vocabulary will be introduced through the following literature review; however, these five terms represent the most commonly encountered across the various theories.

CHAPTER 2

REVIEW OF RELEVANT COGNITIVE LITERATURE

Earliest Memory Discussions

An early contributor to the field of psychology in America was physician, psychologist, and philosopher William James. Starting in 1876, while a physiology professor at Harvard, James is credited with establishing the first true course on psychology. By 1890, he had finished writing *The Principles of Psychology*, an influential book that served to establish mental sciences alongside biological.[1] In the final chapter, James offers a broad explanation of human memory as it was understood at the time. Though many aspects of James' particular examination are dated by today's standards, he outlined key concepts for the first time that would become the basis for later cognitive science studies and methods.

For example, James differentiated between two separate components of memory: primary and secondary. Primary memory, per James' description, is that of the immediate consciousness. Those sensory inputs that are immediately available from the environment but have not yet faded from an individual's attention comprise this primary memory store.[2] In today's language, this idea most closely resembles short-term memory. Conversely, secondary memory is the recollection of a former "state of mind."[3] This separate store encompasses all previous events, knowledge, and other sensory input that

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1. Horace Kellen, William James: American Psychologist and Philosopher, 2014, In *Encyclopedia Britannica online*, retreived from https://www.britannica.com/biography/William-James.

2. William James, *The Principles of Psychology* (New York: Dover Publications, Inc., 1890), 146–47.

3. Ibid., 648.

has since fallen out of an individual's conscious thoughts but can be recalled. Secondary memory is similar to the idea of long-term memory in modern studies. Though James' writings equate more to personal musings, observations, and theories not based on empirical evidence, his idea of separate memory components would eventually be adopted and studied rigorously by others.

Miller's Magical Numbers

Cognitive science and memory theories would remain largely unchanged for the better part of sixty years. The next major voice in this field was George A. Miller. In 1955, Miller presented an article to the Eastern Psychological Association that would become a landmark study in cognitive science. In this study, Miller examined two kinds of limits on human memory: capacity limits on absolute judgement of stimuli and limits on immediate or short-term memory (STM).[4] For the purposes of this literature review, we will focus on the later aspect.

Some of the data Miller examined in his study regarded the finite span of STM. Through some experiments, the author concluded that the limit of STM recall is approximately seven objects at a glance.[5] Miller further made a distinction between a single piece of information and a chunk, coining two terms to best illustrate this difference:

> I have fallen into the custom of distinguishing between *bits*[6] of information and *chunks* of information. Then I can say that the number of bits of information is

4. George Miller, "The Magical Number Seven, plus or Minus Two: Some Limits on Our Capacity for Processing Information.," Psychological Review 101, no. 2 (1956): 344.

5. Ibid., 348.

6. emphasis George Miller.

> constant for absolute judgement and the number of chunks of information is constant for immediate memory. The span of immediate memory seems to be almost independent of the number of bits per chunk, at least over the range that has been examined to date. The contrast of the terms *bit* and *chunk* also serves to highlight the fact that we are not very definite about what constitutes a chunk of information…We are dealing here with a process of organizing or grouping the input into familiar units or chunks, and a great deal of learning has gone into the formation of these familiar units.[7]

With the advent of the term chunk, Miller delivered a possible means for augmenting the "fixed" span of memory for the first time in cognitive science. Though STM was limited by a fixed number of chunks, Miller postulated that the amount of information contained therein may be expanded by recombining sensory input.[8]

Miller dubbed these recombination efforts "recoding," which describes the actual process of grouping and organizing the "input sequence" into new units (chunks). By recoding these bits of information into larger chunks, a person is able to exceed the fixed memory span. For example, in Morse code, a person would first hear dots and dashes individually (each representing one *bit* of information, in Miller's terminology).[9] After some training, the same person is able to combine a series of these inputs into letters (the first chunk). These letters can then be grouped into words, sentences, and finally paragraphs. In a similar manner, according to Miller, a subject might be able to increase the amount of data in their STM by chunking more bits of information together. With the development of the concept of chunking and the seven-item limit in STM, George Miller

7. Ibid.

8. Ibid.

9. Ibid., 349–50.

provided a foundation upon which further research into the limits of human memory would be tested.

Revisions on Mental Storage Capacity in Short-Term Memory (STM)

In the decades following Miller's address, capacity limits (e.g. Miller's seven-item limit) became a contentiously debated topic within the cognitive science community. In 2000, Nelson Cowan, Distinguished Professor of Psychology at the Working-Memory Laboratory at the University of Missouri promoted his hypothesis that capacity limits were actually closer to four items and that, "Miller's reference to a magical number…was probably a rhetorical device. A more central focus of his article was the ability to increase the effective storage capacity through the use of intelligent grouping or "chunking" of items. He ultimately suggested that the specific limit of seven probably emerged as a coincidence."[10]

Capacity limits would continue to be an area of interest for researchers. In 2004, Fernand Gobet and Gary Clarkson, researchers at the University of Nottingham, UK, designed an experiment to test the hypothesized capacity limits from competing structural memory theories. The results showed an even smaller limit to the capacity of STM of two to three chunks.[11] Different still were the results of a study by Fabien Mathy and Jacob Feldman in 2011 that attempted to quantify a chunk in definitive terms ("a unit of maximally compressed code").[12] These researchers found the "true limit" to be three to

10. Ibid., 87.

11. Fernand Gobet and Gary Clarkson, "Chunks in Expert Memory: Evidence for the Magical Number Four ... or Is It Two?," *Memory* 12, no. 6 (2004): 746.

12. Fabien Mathy and Jacob Feldman, "What's Magic About Magic Numbers? Chunking and Data Compression in Short-Term Memory," *Cognition* 122 (2012): 360.

four chunks but that this limit primarily depended on the complexity of the memorized material. Mathy and Feldman equated this four-chunk limit to approximately seven uncompressed items, reinforcing Miller's original number.[13]

Wading further into this debate and determining an exact number for the STM capacity limit is outside the scope of this particular review. Rather, the important idea is that the capacity limits first postulated by Miller in 1956 are still supported by modern evidence, albeit modified according to new studies. These limits to STM ultimately resulted in the formation of several competing theories to explain this phenomenon and its interactions with other aspects of memory overall.

"Chunking" Expanded

In 1973, a general theory of cognition was developed that expanded on Miller's ideas of chunking as a means to explain the differences between the visual processing systems of master and amateur chess players. The authors of this theory, William Chase and Herbert Simon, built on previous research of Simon and K.J. Gilmartin.[14]
Chase and Simon's theory assumed the following: a large number of patterns are stored in long-term memory (LTM), a mechanism exists to quickly access this LTM information, the names of these patterns are stored in short-term memory (STM), and a scanning process exists to detect important features (in this case, locations of chess pieces on a board).[15] Chase and Simon concluded,

13. Mathy and Feldman, "What's Magic about Magic Numbers," 346.

14. William G. Chase and Herbert A. Simon, "The Mind's Eye in Chess," in *Eighth Annual Carnegie Symposium on Cognition,* ed. William G. Chase (Pittsburgh: Academic Press, 1972), 249–251.

15. Ibid., 244–46.

> There is a very large repertoire of patterns in long-term memory—patterns that are held together by a small set of chess relations something like those we found in our earlier research. Second, there is a mechanism that scans the board, that recognizes pieces and the functional relations between pieces, and that finds the important pieces to build these little patterns around. And third, there are severe limits on the capacity of short-term memory, where the internal names of the patterns are stored. [16]

Importantly, not only did this theory account for the memorized patterns, but also for new, structurally different patterns that were functionally related in some way to the old. Someone with expertise in their field may be better at perceiving these newer patterns, whereas a novice would have difficulty due to a smaller bank and less discipline-specific knowledge stored in LTM.[17,18]

Chase and Simon's research served to expand on Miller's earlier work and provided a well-supported cognitive theory regarding expert memory based on studies of the time. The primary limit on this research was the focus on visual processing systems alone without mention of the other sensory modalities; however, this was likely outside the scope of this particular study that examined chess skill. Nevertheless, this research influenced future comprehensive cognitive theories, some of which will be discussed in further detail during the course of this paper.

Incorporating the Long-Term Memory (LTM)

In 1988, Nelson Cowan further expanded the concept of chunking in structural memory by suggesting that STM is actually "an activated portion of long-term

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16. Ibid., 249.

17. Ibid., 251.

18. Fernand Gobet, "Expert Memory : A Comparison of Four Theories," *Cognition* 66 (1998): 118.

memory."[19] Cowan's memory model included two components that applied across senses: the activated portion of LTM and the "focus of attention." The latter component was thought to be where chunking occurred and where subjects encountered capacity limits.[20] However, Cowan later noted in a 1999 review that the major problem with this view was understanding the links that seemed to exist between elements in STM not previous connected in LTM. Cowan's solution, based on reevaluated data, was that long-term memories formed concurrently with STM tasks. More specifically, the LTM (through the focus of attention) functioned to chunk newly presented items into new structures.[21]

Overall, Cowan's research supports that LTM has a larger role in active memory than mere storage of information and that chunks form both in LTM and STM. Cowan further asserts, "…although the mechanisms of short-term memory are separate from those of long-term memory, they are closely related."[22] This close relationship between long and short-term memory stores would be echoed by other researchers in the cognitive field, albeit with different structural models.

Atkinson and Shiffrin's Contributions

Following Miller's 1956 study, researchers R.C. Atkinson and R.M. Shiffrin were the next immediate contributors to this area of research. Their analysis, *Human Memory:*

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19. Nelson Cowan and Zhijian Chen, "How Chunks Form in Long-Term Memory and Affect Short-Term Memory Limits," in *Interactions Between Short-Term and Long-Term Memory in the Verbal Domain*, ed. Annabel Thorn and Mike Page (Psychology, 2008), 86.

20. Ibid., 89–90.

21. Ibid., 103.

22. Ibid., 104.

A Proposed System and its Control Processes, outlined a three-part memory model.[23] A comprehensive review of Atkinson and Shiffrin's study is outside the scope of this literature review, so the following section will primarily focus on the separate discussions of the authors' proposed memory structure and control processes (both fixed and subject-controlled).

According to Atkinson and Shiffrin, three primary structural components exist: the sensory register (SR)—where sensory information is initially received; the short-term store (STS)—the equivalent of today's STM; and the long-term store (LTS) —modern LTM.[24] Figure 1 illustrates the basic structural interactions of these three elements according to the authors of this study.

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23. Richard Atkinson and Richard Shiffrin, "Human Memory: A Proposed System and Its Control Processes," in *The Psychology of Learning and Motivation*, ed. K.W. Spence and J.T. Spence, vol. 2 (New York: Acadmic Press, 1968), 90.

24. Ibid.

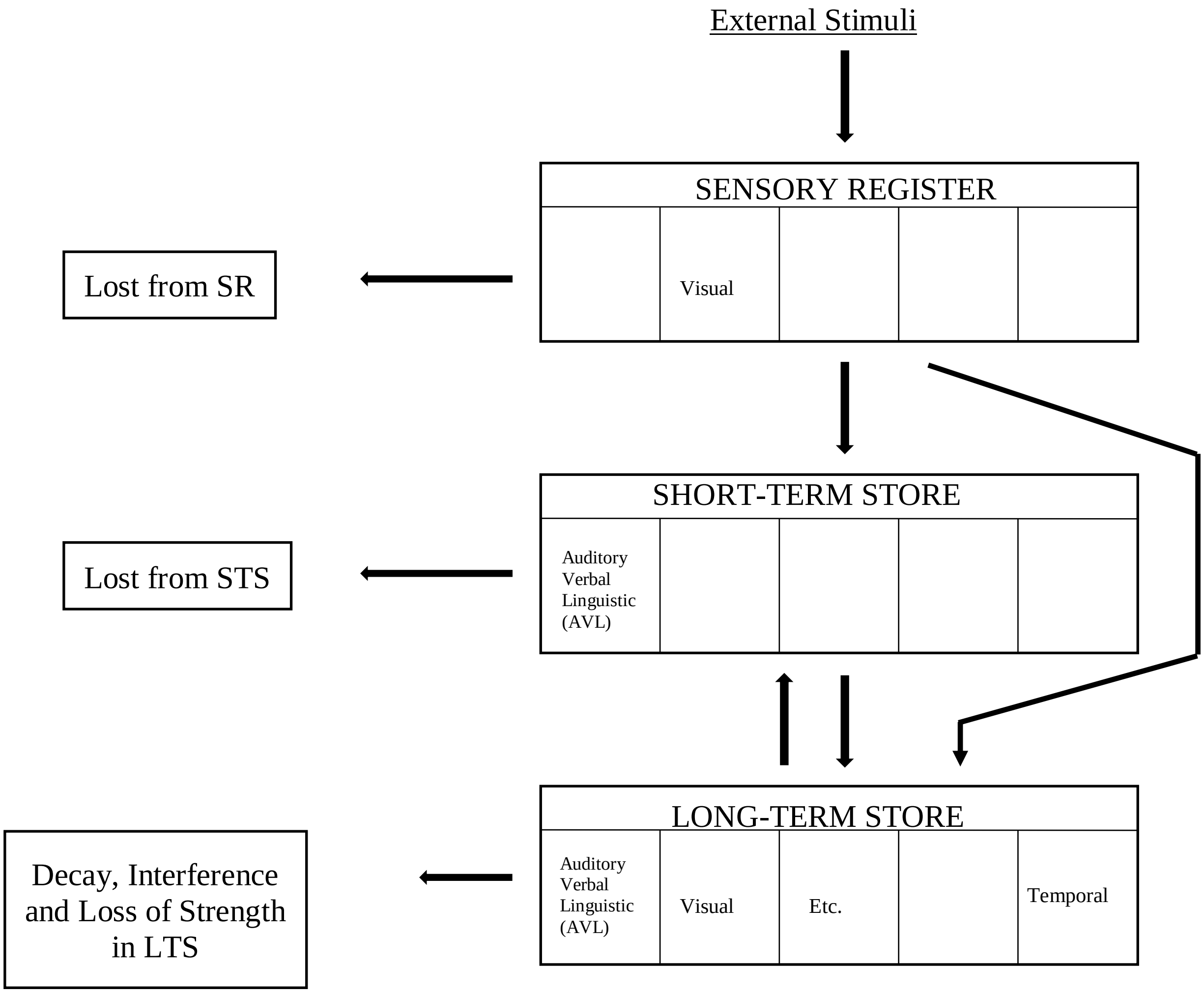

Figure 1. Atkinson & Shiffrin's three-part memory model [25]

In the SR, information either decays and is lost or is passed to a higher order of the system. According to Atkinson and Shiffrin, the received information is then categorized in the appropriate "sensory dimension."[26] At the time of its publication, the only sensory modality understood with certainty was the visual register, as seen in Figure 1; however, the authors left the possibility open to other sensory registers pending future research.

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25. Ibid., 93.

26. Ibid., 92.

The STS was the second major component in the authors' proposal.[27] Information in the STS also decayed like the SR but at a slower rate. Through various subject-controlled control processes this decay can be overcome by transferring the information to the LTS. According to Atkinson and Shiffrin, once in the LTS, information was "relatively permanent" and organized by sensory input.[28]

Figure 1 also depicted the possible interplay between each level of memory, largely accomplished by the will of the subject. Information would be received in the SR, "scanned" to assess overlap with information already in the LTS, and new information would then proceed to the STS. Transfer to the LTS would occur through various control processes (rehearsal techniques) at the subject's discretion. Atkinson and Shiffrin also noted that transfer could occur directly from the SR to the LTS, though evidence of this pathway was minimal at the time. Finally, transfer could also occur from the LTS to the STS through recall of previously stored information (e.g. problem solving, critical thinking, recalling past events, etc.).[29]

The researchers also addressed opposition to their multicomponent theory from various researchers in support of a single-memory structural plan. Opponents claimed that a single structure would be simpler; however, the authors pointed out that a single memory system would need to be far more complex to account for the same data and processes. Thus, according to Atkinson and Shiffrin, the claim of a "simpler" single

27. Ibid.

28. Atkinson and Shiffrin, "Human Memory," 93.

29. Ibid., 94.

component system was not possible.[30] For further support of this conclusion, the researchers drew attention to studies on patients with brain lesions. Often, their short-term memory (STM) remained intact while long-term recall was impossible and vice versa. In a solitary memory framework, the aforementioned cases would not have been possible.[31]

As previously mentioned, control processes were those devices used by the subject in order to aid in transfer from one level of memory to another. These methods varied greatly on an individual basis and are therefore not structurally permanent aspects of memory.[32] At the most basic level, a control process could be giving one sensory input more attention than others, thus aiding in the transfer from sensory register to short-term store. Rehearsal techniques were a particularly prominent control process according to Atkinson and Shiffrin. Through rehearsal, the initial STS information would be regenerated and prolong the initial decay period.[33] These rehearsal techniques may include, but are not limited to, methods such as grouping, reorganizing, recoding, and the previously discussed chunking strategies of Miller.[34] Additionally, Atkinson and Shiffrin also introduced the concept of a "rehearsal buffer" for when multiple stimuli are being rehearsed simultaneously. In this case, one of the items being rehearsed would be replaced by a new item in need of rehearsal, so each item would receive some rehearsal

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30. Ibid., 96.

31. Ibid.

32. Ibid., 106.

33. Ibid., 111.

34. Ibid., 116.

time. The analogy used by the researchers was a bin containing a fixed number (*n*) of items. A new "item" then enters the bin and knocks and older item out (still containing *n* items).[35] This concept of a buffer system would continue into several prominent models of memory that would follow Atkinson and Shiffrin's research.

Overall, Atkinson and Shiffrin's research provided a detailed framework for memory based on then-current trends and evidence. Their three-tier approach to memory was a new idea and attempted to reconcile several issues with the mostly-accepted single-memory theories of older research. While viewed through the lens of modern cognitive psychology, facets of this research are clearly outdated or sparse on support, yet it effectively accomplishes their primary objective to "set forth a general framework within which specific models can be formulated."[36] Within three decades of Atkinson and Shiffrin's initial theory, several competing theories would emerge, all trying to address the arising issues with the earlier memory models.

Template Theory and Working Memory

The template theory (TT) developed by Fernand Gobet (researcher at the University of Liverpool) and Herbert Simon was formulated as an extension to Chase and Simon's chunking theory. To briefly summarize, Chase and Simon studied chess players of different skill levels and found that through practice, players stored patterns of frequently encountered chess pieces in certain positions as various chunks in LTM. Varying with the skill of the player, these chunks allowed players to assess possible

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35. Ibid., 112.

36. Ibid., 91.

moves and their consequences by filtering through their stored information and select the best potential outcome. Chase and Simon concluded a master's more detailed chunks in LTM allowed them to more easily recognize more patterns on the chessboard than amateurs. When random positions were presented, fewer patterns existed, and the master's edge over other players was diminished.[37]

According to Gobet and Simon, the most prominent shortcoming of Chase and Simon's initial theory is that it attributes the master's ability advantage primarily to short-term memory (STM) processing. In reviewing data from their study, the authors show that chunking in STM alone is unable to completely account for the masters' expanded memory. Specifically, Miller's proposed seven-item limit in STM would have been exceeded in this experiment. To account for this result, Gobet and Simon propose that some of those chunks are actually encoded directly to LTM, rather than being wholly processed by STM and later transferred.[38]

In their revised theory, LTM is used in addition to STM and expands the capacity for storage by building large chunks or "templates" in LTM. The primary difference between a chunk and template is that while chunks are smaller and simpler groupings of information, templates are "high level patterns that can change their aspect slightly."[39] Template configurations are large chunks changed by adding various information to

37. Fernand Gobet and Herbert A. Simon, "Templates in Chess Memory: A Mechanism for Recalling Several Boards," *Cognitive Psychology* 31 (1996): 2.

38. Ibid., 16.

39. Alessandro Guida et al., "How Chunks, Long-Term Working Memory and Templates Offer a Cognitive Explanation for Neuroimaging Data on Expertise Acquisition: A Two-Stage Framework," *Brain and Cognition* 79 (2012): 222–23.

hypothetical "open slots" while retaining their overall identity. Alessandro Guida et al. provide the novel metaphor of a train station (the template) that may or may not be filled with various trains (the available slots)."[40] The train station always remains the same regardless of which trains fill the various platforms.

While the authors of the study promoted the idea that templates were primarily accessed through visual cues in the STM, they also allowed the possibility of other environmental or verbal cues alongside the visual.[41] Additionally, in a later survey, Gobet affirmed that template theory was not limited to chess, but rather included any field requiring expertise. Several factors are required for template theory to apply: a large knowledge base of templates, "a large database of chunks," and links (retrieval structures) from the chunks to the knowledge base in STM.[42] Thus, expertise in "knowledge-rich" domains takes a large amount of time to develop because these three domain-specific aspects must be combined into a cohesive network.[43]

Though Gobet and Simon's template theory focused primarily on visual cues in the domain of chess, little exists to prevent this theory from being applied to different fields of expertise (e.g. music) using different sensory modalities such as auditory cues. This expansion answered the shortcomings of Chase and Simon's original chunking theory. While Gobet and Simon made persuasive arguments for their theory in the

40. Ibid., 222.

41. Gobet, "A Comparison of Four Theories," 127.

42. Ibid.

43. Ibid.

context of a rapidly developing cognitive field, other researchers also developed competing theories during this time.

Skilled Memory Theory and Long-Term Working Memory

Another cognitive model of memory to emerge from Chase and Simon's study was the skilled-memory theory of William Chase and K. Anders Ericsson. Chunking theory's inability to account for experts' memory for domain-specific material and their ability to memorize large amounts of rapidly presented material prompted the creation of the skilled-memory theory.[44] Chase and Ericsson's study rectified these shortcomings through examining experts' domain-specific memory capacity focusing on:

1. Information is encoded alongside "cues" related to prior knowledge
2. Time required to encode and retrieve information decreases with practice
3. Retrieval structures are established in LTM[45, 46, 47]

A well-known example of retrieval structures is the "method of loci" where a subject encodes the material to be memorized with locations familiar to the subject. By imagining the specific locations, subjects are able to recall the associated material more easily.[48] For example, if a subject is memorizing a series of 10 playing cards, each playing card might be visualized with a specific place in a mental reconstruction of the subject's own home. By "walking through" this mental home and "seeing" the playing cards, subjects are able to reliably recall the needed information. Several years after

44. Ibid., 119.

45. Ibid.

46. William G. Chase and K. Anders Ericsson, "Skill and Working Memory," *Psychology of Learning and Motivation - Advances in Research and Theory* 16 (1982): 56–57.

47. K. Anders Ericsson, "Memory Skill," *Canadian Journal of Psychology* 39, no. 2 (1985): 188.

48. Gobet, "A Comparison of Four Theories," 120.

developing the skilled-memory theory, Ericsson partnered with Walter Kitsch to expand that study into the more comprehensive Long-Term Working Memory (LT-WM) theory.

LT-WM shares some common traits to the previously discussed Template Theory (TT) of Gobet and Simon. Both theories attempt to address memory capacity in experts, expanding on the earlier chunking theory of Chase and Simon, and both incorporate the LTM as a key component of the seemingly expanded memory properties of experts. LT-WM and TT differ in that, according to LT-WM, an expert does not create highly sophisticated templates in LTM, but rather creates complex associations between encoded information and sets of retrieval cues in LTM. According to Guida et al., in a recent review of several theories of memory in experts,

> In order to retrieve the encoded information, the expert must reinstate the encoding conditions by using the same set of retrieval cues. Long-Term Working Memory becomes available (but restricted to the field of expertise) when a set of cues becomes a stable structure in LTM: *a retrieval structure.*[49] Ericsson and Kintsch's theory…applies the same three principles: meaningful encoding, structured retrieval, and acceleration of encoding and retrieval. [50]

These three principles are the three key steps in expert memory according to LT-WM theory. Information is converted (encoded) into meaningful groups, a retrieval structure is created, and with practice, these processes occur faster over time.[51]

Figure 2 outlines a classic example of a retrieval structure first used in Chase and Ericsson's 1981 theory proposal as well as Ericsson's 1985 updated article on skilled

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49. Emphasis added.

50. Guida et al, "Chunks…Two Stage Framework," 223.

51. K. Anders Ericsson and Walter Kintsch, "Long-Term Working Memory," *Psychological Review* 102, no. 2 (1995): 239.

memory. Ericsson and Kintsch again used this same example in the 1995 LT-WM expansion, and it will serve as an appropriate discussion point here, as well.

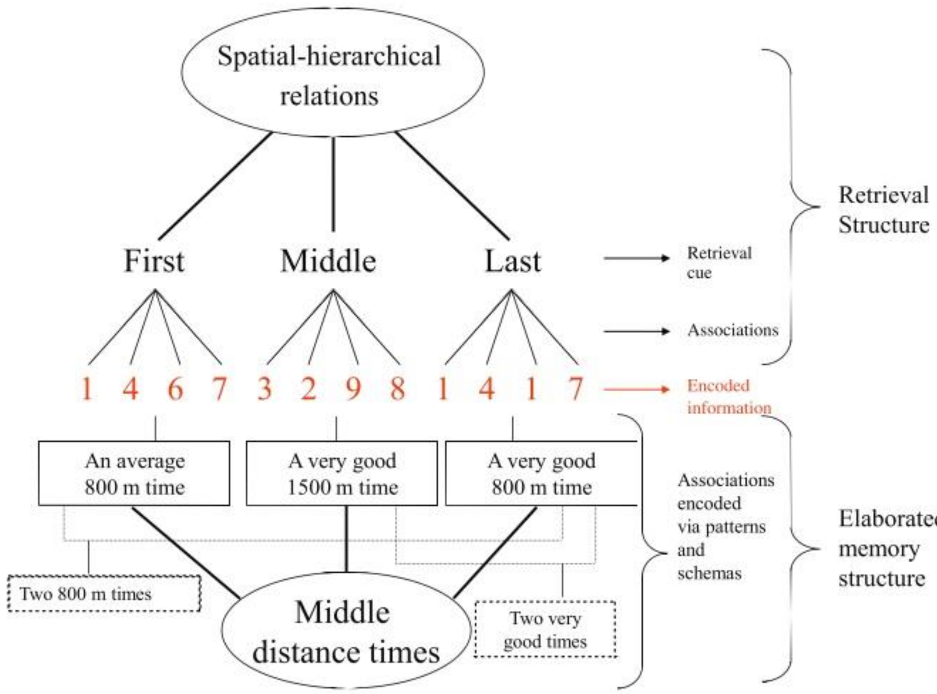

Figure 2. Example of a retrieval structure [52]

Figure 2 refers to a subject from Ericsson's original study, S.F., who used knowledge of running times as a part of a retrieval structure for memorizing a string of random digits. The center number of the figure, 146732981417, is the digit sequence S.F. was asked to recall. In order to do so, S.F. encoded the digits as running times, e.g. 1 minute, 46.7 seconds as the "first" cue, 3 minutes, 29.8 seconds for the "middle" cue, and 1 minute, 41.7 seconds for the "last" cue. Since the subject already had a comprehensive knowledge of race times, encoding for this already established pathway allowed the

52. Guida et al, "Chunks…Two Stage Framework," 224.

subject to recall the string of digits.[53] Additionally, Ericsson and Kintsch outlined supplementary associations that could also be made in the retrieval structures to create an "integrated memory representation." For example, the last two times were both "very good times," while the first and last were "good 800 m times." These additional associations assist in recall by relating different units of information to each other within the retrieval structure creating a more detailed, comprehensive representation.[54]

The LT-WM theory has been criticized for being vague concerning the nature of the hierarchal structure of retrieval cues as well as a lack of specific time parameters for encoding procedures (e.g. how much time is required to encode information into an elaborate retrieval structure). The result is that, according to Gobet, more than one interpretation for the theory is possible.[55] Though plausible, it seems that the differences separating TT and LT-WM theory are less pronounced than their similarities. These differences largely come down to a vocabulary choice: "template" or "retrieval structure." Additionally, LT-WM has been shown to be highly applicable across several domains, including mental calculations, dinner orders, medical expertise, and chess.[56]

Working Memory Theory

In 1974, Alan Baddeley and Graham Hitch began work together on a comprehensive memory theory investigating the link between STM and LTM. This work

53. Ericsson and Kintsch, "Long-Term Working Memory," 215–17.

54. Guida et al, "Chunks…Two Stage Framework," 223.

55. Gobet, "A Comparison of Four Theories," 125.

56. Erisson and Kintsch, "Long-Term Working Memory," 234–38.

was a response to several key criticisms of assumptions made by Atkinson and Shiffrin's memory model. These assumptions were:

1) Holding information in STM would eventually equal transfer to LTM.
2) STM was essential for information to be stored in LTM.
3) STM played a considerable role in overall cognition.[57]

Regarding the first assumption, studies since 1968 had shown that more mindful, elaborate processing facilitated better learning, rather than assuming automatic transferal from STM to LTM. The last two assumptions were scrutinized because patients who suffered from impaired STM did not always have impaired LTM or widespread intellectual deficits.[58] With this knowledge, Baddeley and Hitch proceeded with their working memory study.

In Baddeley and Hitch's work, WM refers to a combination of both storage and processing, whereas STM refers only to "simple temporary storage of information." According to Baddeley, Working Memory (WM) was a natural outgrowth of their understanding of STM.[59] In order to learn more about the structure of WM, Baddeley and Hitch used student volunteers to recreate a scenario of patients with impaired STM.

To create this laboratory situation, the experiment "functionally disabled" participants' STM by requiring a secondary focus alongside the primary experimental

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57. Alan Baddeley, "Working Memory: Theories, Models, and Controversies," *Annual Review of Psychology* 63, no. 1 (2012): 5.

58. Ibid.

59. Ibid., 4.

task.[60,61] For example, the participants were asked to repeat a separate word repeatedly while trying to memorize a number set. The verbal repetition was expected to consume some WM processing capacity resulting in sacrificed primary recall task (digit recall) accuracy. While this hypothesis was true to a certain point, performance in the primary task was "systematically slowed, but [did] not break down."[62] With these results, Baddeley and Hitch proposed a WM system comprised of three elements rather than a unitary system, shown in Figure 3.

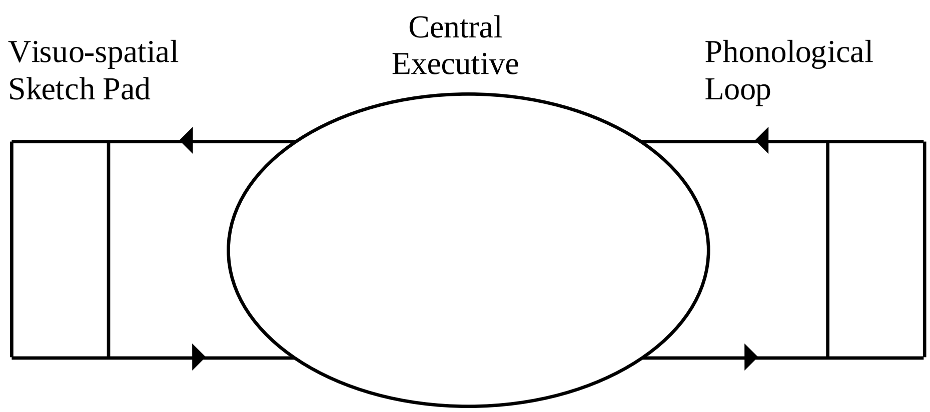

Figure 3. Original working memory structure proposal [63]

This model split attentional focus, controlled by the "central executive," from storage. Storage was separated into a visuospatial sketch pad component for visual information and a phonological loop for verbal. On a large scale, Baddeley and Hitch's model assumed:

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60. Ibid., 5–6.

61. Alan Baddeley and Graham Hitch, "Working Memory," in *The Psychology of Learning and Motivation*, ed. G.H. Bower, vol. 8 (New York: Academic Press, 1974), 49–66.

62. Baddeley, "Working Memory," 5.

63. Ibid., 6.

1) System provides temporary storage and manipulation of information that is necessary for performing a wide range of cognitive activities.
2) System is not unitary but can be split into an executive component and at least two temporary storage systems.[64]

Due to the significant research on verbal STM available at the time, the first component that received attention was the phonological loop. The authors proposed this system was comprised of a "brief store" and a rehearsal buffer maintained by verbalizing the material being focused on.[65] Furthermore, the phonological loop accounted for several documented verbal phenomena and was furthermore found to play an important role in the long-term acquisition of vocabulary in children, which provided an evolutionary reason behind its development.[66]

This research also caused Baddeley to later reevaluate the link between LTM and WM. Prior to the language study, he viewed these systems as separate but interconnected. However, with the loop playing an integral role in the acquisition of language, Baddeley hypothesized a more direct flow of information between the two systems, resulting in the updated model seen in Figure 4.[67] This new model shows WM as several "fluid systems" that are activated as needed and interact with the "crystallized" LTM system that consists of "permanent knowledge."[68]

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64. Ibid., 7.

65. Ibid.

66. Ibid., 10.

67. Alan Baddeley, Susan Gathercole, and Cpstanza Papagno, "The Phonological Loop as a Language Learning Device," *Psychological Review* 105, no. 1 (1998): 170.

68. Baddeley, "Working Memory," 11.

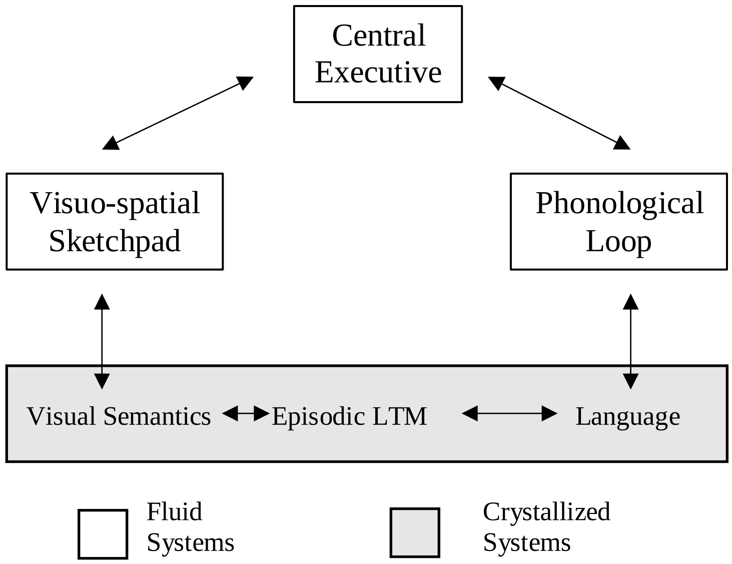

Figure 4. Updated working memory structure proposal [69]

The other component of Baddeley and Hitch's initial model was the visuo-spatial sketchpad. While the phonological loop had been the basis of experiments even before Baddeley, visual and spatial STM were comparatively less understood.[70] Furthermore, Baddeley notes that unlike the rehearsal processes for the phonological loop, the rehearsal process or processes in the visuo-spatial sketchpad are still largely unclear. Most importantly in terms of this review's focus, Baddeley notes the possibility for other subsystems in the sketchpad, such as for movement and gesture or tactile feedback.[71] This idea from the author that other sensory information may be processed by other loops altogether opened a wealth of sensory memory possibilities.

69. Ibid.

70. Ibid.

71. Ibid., 12-13.

The final component of the original model was the Central Executive (CE). Baddeley made four specific assumptions regarding the function of the CE. First, this component served to focus the subject's attention, which was needed in working through complex tasks. Second, the CE had to be able to effectively divide attention between simultaneous sensory streams of information (e.g. concurrent verbal and visual information). Third, the ability to switch attention quickly between tasks was required. Finally, as the CE acted as an interface between WM and LTM, it had no additional storage capacity outside of the other subsystems.[72]

According to Baddeley, this last assumption created issues within his model. If the CE was to act as the coordinator between subsystems of WM and LTM without any storage component, the method in which it combined the various information from two distinct systems into a single, integrated code was not yet understood. In order to account for this issue, Baddeley hypothesized the existence of a fourth component of WM, the episodic buffer (EB).[73] The EB functions as the missing "storage system" for the CE and holds "integrated episodes or chunks" in an assimilated, multimodal code with limited capacity.[74] Most importantly, the EB finally accounted for the cognitive process of chunking, allowing for information from different systems to be processed and combined into larger units. The updated model including the EB is shown below in Figure 5.

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72. Ibid., 14.

73. Alan Baddeley, "The Episodic Buffer: A New Component of Working Memory?," *Trends in Cognitive Sciences* 4, no. 11 (2000): 417.

74. Baddeley, "Working Memory,"15.

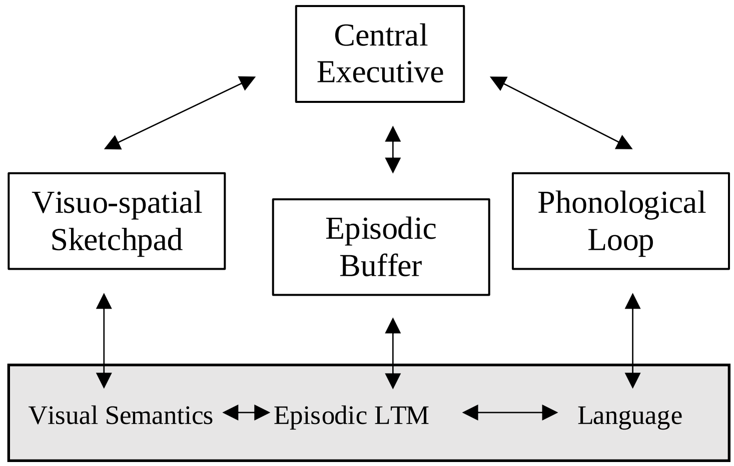

Figure 5. Updated working memory structure proposal including EB [75]

Baddeley's updated WM model is particularly intriguing for several reasons. Foremost, the latest model accounts not only for the cognitive process of chunking, but does so in a way that operates across sensory modalities. With the EB, visual, spatial, and verbal information could potentially be given direct attention by the CE and chunked together for later recall. Moreover, Baddeley noted that other subsystems for other sensory input may exist and intentionally created this model so that it would be adaptable to future studies.[76]

To address some of the opposition his theory met, Baddeley noted that his theories are not completely opposed to other memory models previously discussed. Rather, these theories used different language and illustrated detailed examples of how WM and LTM interact through templates or retrieval structures.[77] The following sections will focus on Baddeley's model of working memory as it pertains specifically to music.

75. Baddeley, "Episodic Buffer," 421.

76. Baddeley, "Working Memory," 14.

77. Ibid., 18.

CHAPTER 3

REVIEW OF RELEVANT MUSIC LITERATURE

The previous chapter examined several landmark studies in cognitive science as well as contrasting structural theories of memory. However, most of the studies focused on verbal, spatial, and visual memory with little emphasis on tactile or auditory senses, especially those not pertaining to verbal communication. In the last several decades, numerous researchers have sought to apply this cognitive knowledge to the field of music. This section examines the most important facets of this area of research as it pertains to conducting and the internalization of scores: chunking, retrieval structures, and working memory.

Chunking in Music

The cognitive mechanism of chunking has been a part of numerous studies of music and memory. Theorists Lerdahl and Jackendoff, for example, examined the hierarchal framework of music and the components that most affect these cognitive structures.[78] The authors dissected music according to grouping, meter, and pitch. From Lerdahl and Jackendoff's perspective, these components had their own units and "combinatorial principles," further described as,

> The basic unit of grouping is a group of one or more adjacent notes in the musical surface; adjacent groups can be combined into larger groups. The basic unit of metrical structure is a beat, a point in time usually associated with the onset of a note in the musical surface. Beats are combined into a metrical grid, a hierarchical pattern of beats of different relative strengths …the basic unit of pitch structure is a note belonging to a tonal pitch space characteristic of the musical idiom; the

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78. Ray Jackendoff and Fred Lerdahl, "The Capacity for Music: What Is It, and What's Special about It?," *Cognition* 100, no. 1 (2006): 33.

> concatenated notes of a melody are combined hierarchically to form a pattern of tension and relaxation called a reduction.[79]

The authors continued that all of these various musical domains interact with each other, creating a comprehensive cognitive picture in a listener's mind.[80]

A similar cognitive phenomenon was described by Diana Deutsch in several publications, most recently in her edited collection of research, *The Psychology of Music*. In a chapter regarding grouping mechanisms in music, Deutsch described the method in which "our auditory system is presented with a set of low-level elements." These components were then combined into various groupings such as timbre, dynamics, spatial location, and pitch. Similar to the hierarchal structures proposed by Lerdahl and Jackendoff, Deutsch permitted that these low-level structures can be built to serve higher level functions such as intervallic relationships, chords, rhythmic patterns, and phrases that occur within a "highly elaborate and multifaceted" auditory system.[81]

These discussions of hierarchal musical frameworks described a means for the mind to group large amounts of complex information into more easily digestible, meaningful units, similar to what George Miller described as chunking in 1956. Deutsch noted that dividing the musical surface into "hierarchically organized chunks" enabled major processing advantages by the brain.[82] John Sloboda's research further contended

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79. Ibid., 37.

80. Ibid.

81. Diana Deutsch, "Grouping Mechanisms in Music," in *The Psychology of Music*, ed. Diana Deutsch (New York: Academic Press, Inc., 2013), 185.

82. Ibid., 209.

that musical phrases set off by both tonal and temporal information and are the basic units of musical processing.[83]

In a similar vein, Lawrence Zbikowski incorporated Arnold Schoenberg's theory of "musical coherence" into a cognitive context, which brought further attention to the importance of motivic structures in music. Zbikowski, citing Schoenberg, argues that musical motives are among the most important fundamental units in music, forming the basis of musical comprehension.[84] With motives shaping overall structure, the cognitive backbone of a composition and a subject's ability for recall depends heavily on motivic grouping and related cues.[85] In this way, motives may be the smallest unit in the hierarchal framework of music, with progressively larger phrases and phrase groupings being built from these smaller units. These ideas tie in to the previously discussed theories of Deutsch, Lerdahl, and Jackendoff.

In 2011, Schulze, Mueller, and Koelsch explored specifically whether musical structure influenced encoding and rehearsal in a nonverbal, tonal working memory (WM) task by using structured (notes belonging to one key) and unstructured (notes that are unrelated) five-tone sequences with both musicians and non-musicians.[86] An example of these sequences can be seen in Figure 6.

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83. John Sloboda, *Exploring the Musical Mind: Cognition, Emotion, Ability, Function* (New York: Oxford University Press, 2005) 176–81.

84. Lawrence Zbikowski, "Musical Coherence, Motive, and Categorization," *Music Perception* 17, no. 1 (1999): 38.

85. Christine K. Koh, "Memory and Learning in Music Reproduction" (Queen's University, 2002), 8.

86. K. Schulze, K. Mueller, and S. Koelsch, "Neural Correlates of Strategy Use During Auditory Working Memory in Musicians and Non-Musicians," *European Journal of Neuroscience* 33, no. 1 (2011): 189–96.

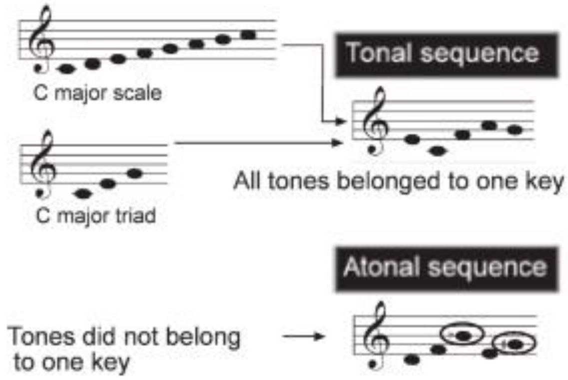

Figure 6. Example of Tonal/Atonal Sequences[87]

The results showed that musicians, but not non-musicians, showed better performance with the structured sequences, "indicating that musicians knowledge about musical regularities [musical structure] helped them to keep the structured sequences in WM."[88] Though the language and vocabulary used to describe these cognitive phenomena varies between disciplines, the importance of cognitive chunking on memory recall has been repeatedly observed.

Role of Retrieval Structures

Regardless of theory, recall depends on some system of "retrieval structures" to pull information previously stored in long-term memory (LTM) back to short-term memory (STM). As early as 1964, prior to the development of more prominent comprehensive memory theories, studies in music showed that understanding the structure and organization of material aided in the memorization and recall of music.[89] In

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87 Ibid., 190.

88. Katrin Schulze and Stefan Koelsch, "Working Memory for Speech and Music," *Annals of the New York Academy of Sciences* 1252, no. 1 (2012): 236.

89. Edgar Ross, "Improving Facility in Music Memorization," *Journal of Research in Music Education* 12, no. 4 (1964): 278.

2002, Roger Chaffin and Gabriela Imreh published a study attempting to isolate which musical features were most essential as retrieval cues in musical recall in expert performers.[90] Though experts in various disciplines had shown "amazing feats of memory" using previously discussed retrieval strategies, the same had not yet been shown with expert musicians. To do so, the authors observed a concert pianist preparing the third movement of J.S. Bach's *Italian Concerto* for performance from memory. Chaffin and Imreh found that in addition to the auditory and motor memory expected in an expert musician, the performer also relied heavily on retrieval structures based on the formal structure of the piece (small-scale phrase and overall form). Through three extended practice sessions (11.5 hours, 8 hours, and 14 hours), records were kept regarding the numbers of times each bar was repeated or used as a starting or stopping place. Overall, bars of significant structural influence were practiced more than others. For example, measures located later in a significant structural section were repeated more often than those at the beginning, suggesting difficulty in recall, aligning with the standard effect of serial recall of items by memory. Additionally, when recall at significant structural points failed, the performer related this to difficulties in their conception of the piece's structure. The authors noted that this hierarchal form embedded in the music needed to be retrieved from LTM at these critical points. In the aforementioned practice sessions, this idea translated to stopping and practicing these

90. Roger Chaffin and Gabriela Imreh, "Practicing Perfection : Piano Performance as Expert Memory," *Psychological Science* 13, no. 4 (2002): 342.

transitions more often to “bring the operation of this retrieval scheme up to the pace of the motor performance.”[91]

In 2007, Chaffin performed a similar experiment under slightly different conditions using Debussy’s *Clair de Lune* as the learning material. In this experiment, the professional pianist had 4.75 hours to prepare for performance, providing details through the process about the formal structure and performance cues she most focused on while preparing. Though the time spent in practice was dramatically shorter from the 1997 study, the process was largely similar.[92] Like the previous study, the pianist focused on specific musical features during practice to establish them as retrieval cues. Chaffin hypothesizes:

> During performance these cues automatically elicit the motor and auditory memories of what comes next and the declarative memory needed to monitor and guide playing. These performance cues provide a necessary safety net for the professional performer, allowing recovery from mishaps and memory lapses.[93]

Throughout the practice session, the pianist was recorded focusing her repetitions and practice primarily on measures with these retrieval cues, as well as those measures directly after. Unsurprisingly, many of these cues also coincided with the beginnings of major sections or smaller phrases of importance.[94] Since these cues are responsible for LTM retrieval of the music, Chaffin notes the increased fluidity of this recall during later sessions, showing that repetition during practice increased the “speed and automaticity of

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91. Chaffin and Imreh, “Practicing Perfection,” 342–48.

92. Roger Chaffin, “Learning Clair De Lune: Retrieval Practice and Expert Memorizatio,” *Music Perception* 24, no. 4 (2007): 391.

93. Ibid.

94. Ibid., 392

retrieval."[95] These results and recorded methods of the pianist also reinforce the reliance on a hierarchal framework for memorization, in this case, the structure of the music.

Chaffin also tried to find evidence of the use of "familiar patterns" to better encode music, such as scales, chords, and arpeggios though there was little behavioral data to suggest the number of patterns in a bar affected memorization.[96] However, Chaffin's definition of a "pattern" seems relatively limited in scope, as musical patterns could be found outside of scales, chords, and arpeggios. Knowledge of harmony or specific compositional features of Debussy would surely aid in LTM retrieval alongside structural features. Additional melodic patterns outside a typical scale or arpeggio could be isolated and used in recall, as well. I relate knowledge of these patterns and features in music to knowledge of grammar and vocabulary in language. In memorizing a speech, grammar may not be the key feature on which to focus, but the knowledge of how language is constructed and should flow would undoubtedly aid in the task.

Similar experiments to Chaffin and Imreh's also yielded familiar results. Aaron Williamon and Elizabeth Valentine of the Royal College of Music and University of London, respectively, designed a study in 2002 exploring the use of "encoding and retrieval of music."[97] However, this study was different in that it used a larger subject pool (22 pianists) separated into four skill levels to test these encoding and retrieval

95. Ibid., 391

96. Ibid.

97. Aaron Williamon and Elizabeth Valentine, "The Role of Retrieval Structures in Memorizing Music," *Cognitive Psychology* 44 (2002): 1.

methods and the relation to expertise. [98] Like both of Chaffin's studies, all pianists focused practice primarily on "structural" bars and less on measures classified as "difficult" by the researchers. As skill level increased, so did the focus on the structural measures in practice sessions. With these results, Williamon and Valentine determined that the "formation and use of retrieval structures develop as a function of expertise."[99]

While these three previously discussed studies frame their results in relation to the expert memory model of long-term working memory (LT-WM), the results are also applicable to the working memory (WM) model of Baddeley and Hitch. In discussing LT-WM, Baddeley writes that he agrees that experts likely use developed retrieval structures to access information in the LTM, but, "I cannot see any advantage in treating this as a different kind of WM rather than a particularly clear example of the way in which WM and LTM interact."[100]

Working Memory Module for Music

With this idea, several researchers in the music field have attempted to expand Baddeley's WM theory. Baddeley and Hitch's original model does not specify whether non-phonological information is processed the same as phonological information, so several studies by various researchers were created to understand whether music was processed by the phonological loop or a separate "tonal" or "musical" loop.[101,102,103]

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98. Ibid.

99. Ibid.

100. Baddeley, "Working Memory," 18.

101. William L Berz, "Working Memory in Music: A Theoretical Model," *Music Perception* 12, no. 3 (1995): 353.

Unfortunately, most research on auditory WM has focused of verbal test material, and while some research exists focusing on tonal information, conflicting results make it difficult to reach definite conclusions. For example, Salame and Baddeley showed in a 1989 study that instrumental music interfered with verbal WM compared to vocal music, drawing the conclusion that two independent WM subsystems were possible: one for verbal information and one for tonal. However, in 1996, Semal et al. showed that pitch similarity of various stimuli had more of an effect on ability for recall than modality (verbal vs. tonal), leading to the conclusion that these stimuli are all processed in a similar system.[104] The researchers Katrin Schulze and Stefan Koelsch set out to reconcile these seemingly conflicting data sets.

To do so, Schulze et al. designed a study that differentiated between the method in which non-musicians and expert musicians process tonal information.[105] Using functional magnetic resonance imaging (fMRI), the researchers found that while both non-musicians and musicians used some of the same neural networks for verbal and tonal WM, musicians used several structures either exclusively for verbal WM or exclusively for tonal WM.[106] To explain these results, Schulze et al. hypothesized that, "based on the

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102. Adam Ockelford, "A Music Module in Working Memory? Evidence from the Performance of a Prodigious Musical Savant," *Musicae Scientiae*, 2007, 5.

103. Thomas Pechmann and Gilbert Mohr, "Interference in Memory for Tonal Pitch: Implications for a Working-Memory Model," *Memory & Cognition* 20, no. 3 (1992): 314.

104. Catherine Semal et al., "Speech Versus Nonspeech in Pitch Memory," *Journal of the Acoustical Society of America* 100, no. 2 (1996): 1130.

105. Katrin Schulze et al., "Neuroarchitecture of Verbal and Tonal Working Memory in Nonmusicians and Musicians," *Human Brain Mapping* 32, no. 5 (2011): 771–83.

106. Ibid., 782.

assumption of functional plasticity induced by music, …musical expertise leads to a network comprising more structures underlying tonal WM."[107] In simpler terms, due to the brain's long-known ability to grow and adapt to suit specific, high level activities (e.g. music), musicians process music with different structures (e.g. tonal loop) than non-musicians. The remainder of this research is focused on this idea that a separate tonal loop for musicians' WM. This concept, in combination with cognitive chunking ideas that are accounted for within Baddeley's model, form the basis for a powerful pedagogical tool that could serve conductors in their process of learning and internalizing music, which will be examined more deeply in the coming chapters.

107. Schulze and Koelsch, "Working Memory for Speech and Music," 223.

CHAPTER 4

REVIEW OF RELEVANT INSTRUMENTAL CONDUCTING PEDAGOGY

A variety of textbooks have been and are currently being written concerning instrumental conducting pedagogy. Obviously, many of these texts place a great deal of emphasis on the technical aspects of conducting: baton grip, posture, beat patterns, etc. Some of these books also introduce various aspects of score study such as marking, analysis, and form of various types of music. Fewer still consider the cognitive side of conducting in depth either due to publishing restrictions, time considerations in the actual courses for which they are designed, or unfamiliarity with the cognitive field.

However, several texts exist that mention memorization for conductors. Since one of the goals of this research is to impact current instrumental conducting pedagogy, I will focus primarily on those texts regularly encountered in the undergraduate instrumental conducting course either as a textbook or supplemental resource for this literature review. Max Rudolf's *Grammar of Conducting* is one of the pillars of conducting pedagogy. In a chapter focusing on "score study and preparation of orchestra materials," Rudolf addresses score memorization, cautioning against spending "many hours on memorizing for the purpose of public display," or rather, memorizing for the sake of self-aggrandizement instead of as a means to better serve the music resulting from the score study process.[108] While wise, Rudolf's discussion of memory does not include how to

108. Max Rudolf, *The Grammar of Conducting*, 3rd ed. (New York: Schirmer Books, 1995), 324.

incorporate memory into a score study process. Several other texts fall into a similar vein.[109,110, 111]

Elizabeth Green, by comparison, offers a more detailed discussion about a method in which conductors memorize, though still brief.[112] In the final chapter of *The Modern Conductor* Green noted,

> Memorization is the final step of thorough score study. The mind by nature organizes a sequence of events, grouping them into patterns. Part of the process of score study involves discovering patterns used by the composer in writing any given work.[113]

Without using the same cognitive vocabulary used throughout this document, Green discusses the process of chunking, the same cognitive technique described by Miller in 1956. Green continues with a small discussion about the ways by which memorization occurs in different people, stemming from the mind's ability to compare and contrast sections based on musical features like meter, orchestration, or structure. These elements, according to Green, "[act] as a switch in the tracks; from that point we can make a chart of the differences… helping us memorize both of them." [114] What the author refers to as a track switch could easily be interpreted as a retrieval cue to recover musical information committed to long-term memory.

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109. Frank Battisti and Robert Garofalo, *Guide to Score Study for the Wind Band Conductor* (Ft. Lauderdale: Meredith Music Publications, 1990), 55.

110. Glenn D. Price, *The Eloquent Conductor* (Chicago: GIA Publications, Inc., 2016), 95.

111. Dale Lonis, *Selected Resources for Instrumental Music Teachers*, 6th ed. (Dale J. Lonis, 2014), 57–59.

112. Elizabeth Green and Mark Gibson, *The Modern Conductor*, 7th ed., 2004, 204.

113. Ibid., 205.

114. Ibid.

As proven through a review of standard instrumental conducting literature, with perhaps the exception of Elizabeth Green's text, a lack of discussion exists relating to how human memory functions. As opposed to the "natural outgrowth" approach where memorization simply occurs after a period of study, I believe there is a way to incorporate internalization and memorization into the score study process and conducting pedagogy through awareness of developments in the cognitive field. These ideas will be examined further in the following chapter.

CHAPTER 5

COGNITION, CHUNKING, AND CONDUCTING

Incorporation of Research

As seen through the previous literature review, trends in cognitive research have not been incorporated into instrumental conducting pedagogy with any regularity. Early in this survey, I noted how many conducting texts have been written on the "nuts and bolts" of score study (harmonic analysis, large-scale formal analysis, phrase analysis, etc.). Over time, each conductor develops their own method of working through these musical elements to construct a comprehensive understanding of any piece. A large portion of this development occurs through personal trial and error and finding which methods of score study lead to the greatest retention. The goal of this research is to submit that, with the current body of cognitive research, instructors can eliminate at least some of this uncertainty early in young conductors' development.

It is important to note that this research has already been applied in educational settings previously from elementary school students learning the most basic of melodies to college-aged pianists learning new pieces for performance.[115,116] Moreover, Fernand Gobet, author of the Template Theory, has presented on how aspects of these theories of memory could (and should) be applied in a variety of settings.[117] The goal of this study is

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115. Jennifer Mishra, "A Theoretical Model of Musical Memorization," *Psychomusicology* 19, no. 1 (2005): 75.

116. Pamela D Pike and Rebecca Carter, "Employing Cognitive Chunking Techniques to Enhance Sight-Reading Performance of Undergraduate Group-Piano Students," *International Journal of Music Education* 28, no. 3 (2010): 231.

117. Fernand Gobet, "Chunking Models of Expertise: Implications for Education," *Applied Cognitive Psychology* 19, no. 2 (2005): 183.

not to imply that students (both conducting and otherwise) must have a detailed understanding of the cognitive processes of memory. Rather, with an awareness of the framework of human memory and how it operates, conductors can more effectively study the score, internalizing it earlier in their individual processes and better serving the music overall.

By applying research in working memory to the score study process, I believe there is a means through which we can more effectively teach conductors to memorize and internalize music. The assumptions taken from this point forward are:

1) Baddeley and Hitch's model of working memory (WM) can be applied across disciplines.
2) There exists a musicological/tonal loop in musicians' WM that processes tonal information in a different manner than non-musicians.
3) Musical training and expertise functions to provide a base of information stored in long-term memory that can aid in more efficient recall.
4) Cognitive strategies exist that aid in the memorization process such as the formation of retrieval cues and chunking technique.
5) "Good" memorizers are a product of domain knowledge and practiced technique in lieu of being born with a greater capacity for memory.
6) The following discussions will focus on applications toward western, tonal music.

Furthermore, I would like to echo the conducting pedagogues of the past in noting that memorization of a score is not the end goal of score study. Rather, the objective should always be a deeper understanding of the score and connection with the ensemble. That said, by interweaving past pedagogical techniques with a new understanding of human cognition and memory, a productive balance can be achieved that would benefit all conductors.

The large-scale form of a piece, as well as the phrase structure, supplies the most basic hierarchal information, which is a prime starting point from a working memory perspective. By organizing (chunking) these individual phrases into longer, more meaningful units, an individual can begin internalizing the music using major structural points as musical retrieval cues. What was once a 315 measure movement (far exceeding the capacity limits of human memory) could become three or four large structural chunks. These divisions often reflect major divisions of form (as noted in Chaffin's research), though this is not necessarily a prerequisite. Furthermore, knowledge of overall form stored in a seasoned musician's long-term memory can aid and speed up this storage process.

As fundamental as structural analysis can be in the process of music memorization, I hypothesize other musical features can function as effective retrieval cues, as well. For example, the entrance of a new instrument might serve as a retrieval cue in STM to fully recall the next major musical segment from LTM. Similarly, changes in orchestration, meter, dynamic, harmony or otherwise could serve as retrieval cues. These cues are all formulated and stored throughout the score study process.

Due to previously noted research, I believe that by briefly introducing young conducting students to these concepts, teachers and conducting mentors can enable internalization of music as early in the score study process as discussions of phrase structure. The following is one potential methodology:

1. Lay the foundation for memory and internalization alongside the earliest discussions of score marking.
2. Simplified versions of memory components (short-term and long-term only) are discussed; introduction to the chunking technique.
3. Large and small scale structures discussion; practice in using markings to denote musical structure.
4. Teach how to use effectively use chunking in practice; focus on building students' phrase analyses into larger units.

5. Live conducting session with an ensemble formed from the class to put discussed theories into practice; students assigned short examples to be studied utilizing techniques from class.
6. Concluding discussions with students follow regarding the benefits they experienced when not relying on a score.

This type of early encouragement towards interacting with music away from the score could have far-reaching, positive effects and should be reiterated through future conducting sessions and discussions of score study. Later discussions could add descriptions of retrieval cues and how they factor into internalizing more complex music. Slow and steady incorporation of these mental aspects alongside the physical components of conducting are key to encouraging well-balanced growth. To that end, these proposed methods could enable instructors to move students away from the score and focus on communicating more directly with the ensemble: the overarching goal in any conducting course.

Future Steps

While in many ways the theory of Working Memory (WM) already seems to align with what many conductors have learned from years of study, no substantial research regarding WM and the field of instrumental conducting exist at this time. It is the goal of this research to serve as a springboard into more robust, quantitative studies involving conductors at all levels. With more explorations into these interactions, I hope to either confirm or revise the hypotheses that have been proposed in this study.

In a similar vein, it would be worthwhile (and necessary) to see how these cognitive principles apply to music outside of the tonal realm. It is currently unknown whether some or any of these principles of the “tonal loop” in WM would still apply to atonal, serial, or aleatoric music. It is possible that these other types of music are processed in a separate way using different neural pathways altogether; however, such considerations were outside the scope of this research.

Conclusion

This initial study serves as the first of a multiphase project that will ultimately result in either confirming or modifying these initial hypotheses. The primary goal of this research has been twofold: bring further awareness to the advances in cognitive science to the instrumental conducting discipline and propose a start to its incorporation into current conducting pedagogy. Until now, one’s approach to memorizing scores has likely been developed through a trial and error approach over several years of attending masterclasses, conversations with experienced conductors, and refining individualized systems. While score study will always be as varied as each individual’s conducting style, we can eliminate much of the “guess and check” methodology in studying and internalizing the music that young conductors often encounter thanks to developments in cognitive science. By encouraging and enabling conductors to step away from the score more often and giving them the cognitive tools to do so, there are more possibilities to strengthen their connection with the music, the ensemble, and the audience.

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